DOE/EM-

In Situ Underwater Gamma Spectroscopy System

Deactivation and Decommissioning Focus Area

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INNOVATIVE TECHNOLOGY
Summary Report

In Situ Underwater Gamma Spectroscopy System

OST Reference 2990

Deactivation and Decommissioning
Focus Area

Demonstrated at
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

The purpose of this Innovative Technology Summary Report is to describe the In Situ Underwater Gamma Spectroscopy System, which identifies and quantifies radiological characteristics of objects underwater. Determining the nature and extent of radiological contamination is essential for safely and effectively decontaminating and decommissioning nuclear facilities.

The In Situ Underwater Gamma Spectroscopy System provides near real-time dose rate and isotopic details to guide decisions about handling and disposing of radioactive objects stored in spent nuclear fuel pools. Engineers demonstrated the efficacy of this system at the Idaho National Engineering and Environmental Laboratory as part of a Department of Energy Large-Scale Demonstration and Deployment Project.

Innovative Technology Summary Reports describe waste cleanup technologies developed and tested using funds from the Department of Energy's Office of Science and Technology. The reports compare baseline and competing technologies, considering readiness, performance, regulatory acceptance, commercial availability, and cost. The reports are available online at http://ost.em.doe.gov (under "Publications").

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SECTION 1
SUMMARY

Technology Summary

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in decontaminating and decommissioning nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area of DOE's Office of Science and Technology (OST) sponsors a “Large-Scale Demonstration and Deployment Project” to test new technologies. In addition, developers and vendors showcase new products designed to decrease health and safety risks to personnel and the environment, increase productivity, and lower costs.

Decontamination and decommissioning (D&D) projects at the Idaho National Engineering and Environmental Laboratory (INEEL) must identify and quantify radiological contamination, specifying radioisotopes and concentrations contained in waste objects. As part of this characterization, the In Situ Underwater Gamma Spectroscopy (ISUGS) System identifies and quantifies radioactivity of objects stored or located underwater. The ISUGS System is based on the In Situ Object Counting System (ISOCS) (see Figure 1), which is placed in a watertight vessel. Objects to be characterized are brought to the unit while shielded by the water.

As a modified ISOCS, the ISUGS System includes a submersible unit (see Figure 2) and various modifications to correct the efficiency calculations for underwater applications. Using the same instrumentation and computer software as the ISOCS, the ISUGS System provides dose rate and isotopic details for making regulatory decisions (e.g., determining disposal or decontamination alternatives) about radioactive objects stored in spent nuclear fuel pools or canals. The ISUGS System provides the near real-time information essential for D&D activities, while reducing work force exposure to radiation.

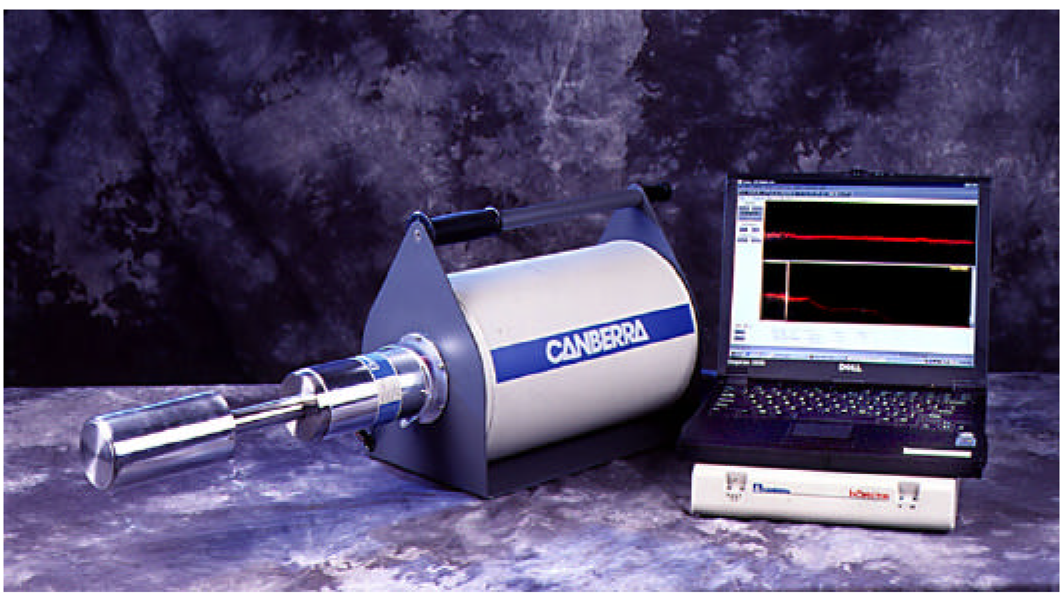

Figure 1. The ISOCS including germanium detector. The detector is placed inside the submersible unit as shown in Figure 3.

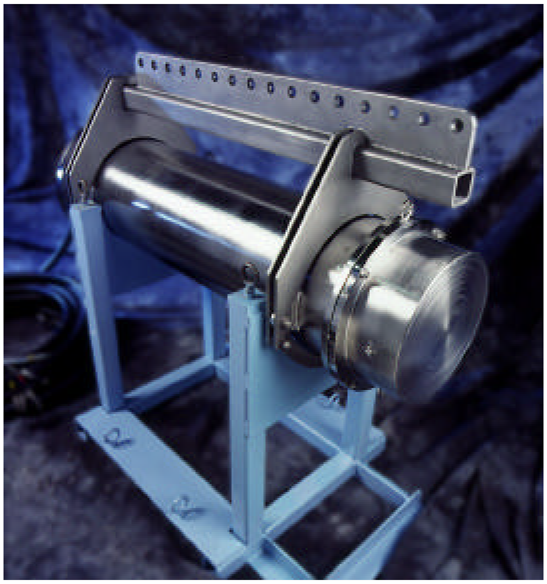

Figure 2. The submersible unit.

The ISUGS System has been mathematically calibrated using a Monte Carlo process to perform efficiency calculations for a wide variety of shapes, sizes, densities, and distances between the detector and area of interest.

This demonstration was designed to determine if the ISUGS System could be used for underwater radiological characterization to meet the INEEL's Radioactive Waste Management Complex waste acceptance criteria by replacing the current baseline technology. The baseline technology involves deploying a radiation detector on a "extendable pole" to measure levels of radioactivity and then collecting samples to identify specific radioisotopes. All waste streams must be properly characterized before disposal. Historically, samples have been collected from this facility and a scaling factor (Tyger 1999—see full reference in Appendix A) has been developed for the specific alpha- and beta-emitting radionuclides. These scaling factors were based on the cobalt-60 and cesium-137 concentrations. A portion of the samples collected and analyzed during this demonstration were used to confirm the scaling factors for the alpha- and beta-emitting radionuclides associated with objects found in the INEEL's Materials Test Reactor canal. This demonstration also provides information necessary to compare reductions in cost, worker exposure, turn-around times for analytical results, and time required for decision making by the D&D program.

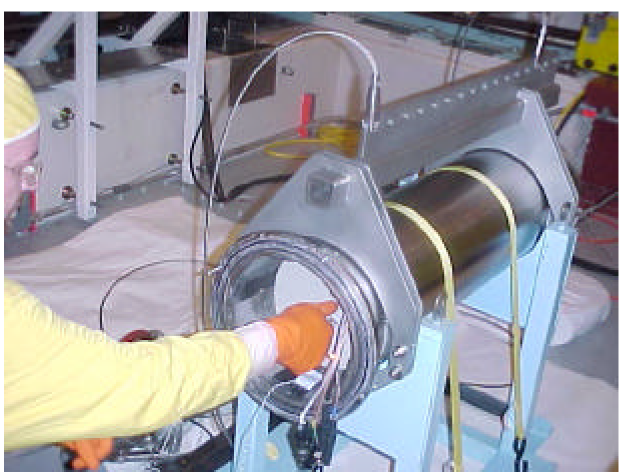

Figure 3. The submersible housing unit with the germanium detector placed inside.

The benefits of using the ISUGS System include:

- Cost reductions for object characterizations – reduction in labor hours and sampling.
- Increased data accuracy and quality – includes isotopic results, compared with the baseline of gross beta/gamma levels with separate sampling required for isotopic analysis of the material.
- Accelerated D&D schedule – shorter characterization times and reduced need for sampling of the contents of objects in the canal.
- In situ near real-time radiological measurements.
- Reduced exposure of personnel to radiation – unit is operated underwater, reducing exposure. Reduced sampling also has the effect of reducing exposure of personnel to radiation.
- No secondary waste stream created.

Baseline Technology

Currently, the radiological characterization process involves the use of a radiation detector on a "extendable pole" to locate and quantify radiation levels near objects in the canal. Samples are collected from the objects to identify and quantify radionuclides. During sampling, a potential for increased worker exposure exists. The sample collection process requires additional safety precautions to shield the sample and prevent the spread of contamination during removal and transport to the laboratory for analysis. Analytical results can take up to three months, delaying decision making and dispositioning of objects being characterized. This process is tedious and time consuming and creates a secondary waste stream.

New Innovative Technology

The innovative technology is based on the ISOCS and uses the same instrumentation and computer software by Canberra. It includes the submersible unit and modifications to correct the efficiency calculations for underwater applications.

Depending on the levels of radioactivity in the canal, the count time for the individual scans (measurements) will vary from 90 to 300 seconds. This technology can operate in a relatively high radiation field (dose rates ranging from 0.050 to > 1,000 R/hour).

This demonstration was also used to evaluate the scaling factor developed for other objects at the Materials Test Reactor. The scaling factor may be useful for other radiological characterization processes involving pools or canals.

Canberra developed this technology for Framatome Inc., which is the service provider.

Demonstration Summary

The ISUGS System was demonstrated at the Materials Test Reactor canal in May 2000 to provide underwater radiological characterization of various objects located inside the canal. The submersible unit was considered to be contaminated; therefore, it was shipped as a hazardous item to the INEEL. Radiological control technicians surveyed the unit at a warehouse located at the INEEL's Central Facilities Area. A certified shipper transported the submersible unit to the Materials Test Reactor, where it was set up by Framatome employees with the assistance of INEEL personnel. The submersible unit, along with the detector and collimators, weighs approximately 500 pounds. Lifting the unit required the assistance of certified hoisting and rigging personnel, who carefully lowered the unit into the canal. For safety reasons, procedures prohibited supporting the unit directly over any fuel racks. The system was attached to the canal wall with a support bracket shown in Figure 4.

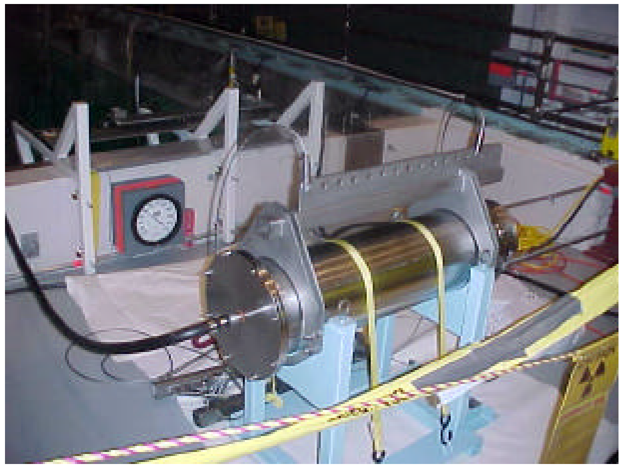

Figure 4. Submersible unit with the wall bracket.

The ISUGS System was lowered into the canal in an area where no fuel rods or other radiological material is located. An extendable pole was used to connect a rope around the object to be scanned, which was then moved into position in front of the ISUGS System. A scan was collected from this area to measure background radiation levels. Different collimators can be applied to the detector as necessary. Once the size of the collimator had been established, objects were transported underwater to the unit for scanning. Scan times typically ranged from 90 to 300 seconds.

Samples were also collected from various objects inside the canal to support baseline technology assessment. These samples were analyzed onsite. From these analytical results, a scaling factor was applied to calculate the alpha- and beta-emitting radionuclides. This method is already approved for the Materials Test Reactor. In addition, program personnel were able to validate their scaling factor calculations by using these samples for specific alpha and beta analyses. This part of the project was also conducted during May 2000.

Key Points

The key points of this demonstration are summarized below. Detailed descriptions and explanations of these results are found in Section 3 of this report.

- Cost reductions in sampling and labor hours
- Increased data accuracy and quality
- In situ near real-time radiological measurements
- Reduced exposure of personnel to radiation
- No secondary waste stream.

Contacts

Technical

Technical Information on the ISUGS System —

Service Provider:

Framatome Technologies, Inc.
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Lynchburg, VA 24506-0935
Point of Contact: Matthew Hernandez
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800 Research Parkway
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Point of contact: Carlton Green, (208) 788-8925 cgreen@canberra.com

Technology Demonstration

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Cost Analysis

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Web Site

INEEL Large-Scale Demonstration and Deployment Project Web address: http://id.inel.gov/lsddp

Licensing

No license was required. The ISOCS and ISUGS System underwater equipment used for this demonstration was provided as a service by Framatome, Inc.

Permitting

No permitting activities were required, although the ISUGS System was radioactively contaminated and shipped in accordance with Department of Transportation Hazardous Material Shipping and Packaging requirements.

Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under “Publications.” The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST reference number for the ISOCS is 2990.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goals and Objectives

The overall purpose of this demonstration was to assess the benefits that may be derived from using the ISUGS System for meeting waste acceptance criteria. The ISUGS System was compared with the baseline technology. The primary goal of the demonstration was to collect valid characterization data to make a legitimate comparison between the ISUGS technology and the baseline technology in the areas of:

- Cost
- Productivity
- Ease of use
- Limitations and benefits.

Description of the Technology

The innovative technology is based on the ISOCS. The ISOCS was demonstrated for free release of facilities in the INEEL LSDDP. What is unique about this technology is that the ISOCS is placed in a watertight vessel and objects to be characterized are brought to the unit while shielded by the water. The ISOCS has been evaluated and verified independently as a significant characterization improvement technology ("Chicago Pile 5 [CP-5] Research Reactor Large-Scale Demonstration Project, Argonne National Laboratory-East," February 1998). The ISUGS System uses the same instrumentation and computer software by Canberra. The system is thus a modified ISOCS and includes the submersible unit (30" in length and 11" in diameter) and extra parameters to correct the efficiency calculations for underwater applications.

Depending on the levels of radioactivity in the canal, the count time for the individual scans (measurements) will vary from 90 to 300 seconds. This technology can operate in a relatively high radiation field (dose rates ranging from 0.050 to > 1,000 R/hour).

The ISUGS System has been designed with the following components:

- Canberra GL0515 Low-Energy Germanium Detector, with an energy range of 3 keV - 2 MeV
- Canberra detector electronics, including transistor reset pre-amplifier and high-voltage power supply
- Single-port, multiattitude liquid nitrogen cryostat and remote detector chamber
- Custom submersible housing with electronics/vent umbilical, and 10 externally mounted interchangeable shielded collimators
- Canberra *InSpector*™ Multi-Channel Analyzer
- A 366-MHz Dell *Inspiron 3500* notebook computer
- A 500-MHz Dell *Optiplex GX1p* desktop computer
- Canberra software programs:
  - Genie 2000 Gamma Acquisition and Analysis
  - Genie 2000 Detector Quality Assurance
  - Genie 2000 Interactive Peak Fit
  - PROcount 2000 Counting Procedures
  - ISOCS

- Wall-mounted, detector support bracket with:
  - Adjustable X-Y slides
  - Dual-elevation wire rope rigging attachments
  - Detector housing strongback with distance measurement device
- Underwater video system with pan, tilt, zoom, and lighting capabilities.

System Operation

Table 1 summarizes the operational parameters and conditions of the ISUGS System demonstration.

Table 1. Operational parameters and conditions of the ISUGS System demonstration.

Working Conditions	
Work area location	• Test Reactor Area – Materials Test Reactor canal (Test Reactor Area-603)
Work area access	Access controlled by D&D project through use of fencing and posting
Work area description	• In order to gain access to Materials Test Reactor, the facility manager was notified. • The canal of the Materials Test Reactor is a radiologically controlled area, requiring personal protective equipment (PPE) and radiological control technician oversight.
Work area hazards	• Tripping • Heavy equipment operations • Temperature extremes • Radiologically Controlled Area requiring PPE and radiological control technician oversight.
Equipment configuration	The ISUGS System was transported to the work site by a certified hazardous material driver and moved to the work area by the test engineer and radiation control technician, after receipt inspection at the Central Facilities Area.
Labor, Support Personnel, Specialized Skills, Training	
Work crew	Minimum work crew: • 1 field (Test Reactor Area) operator • Framatome operator • 1 radiological control technician
Additional support personnel	• 1 data collector • 1 test engineer • 1 health and safety observer (periodic)
Specialized skills/training	• Framatome representatives are trained in the operation of the ISUGS System • Occupational Safety and Health Administration
Waste Management	
Primary waste generated	No primary wastes were generated.
Secondary waste generated	No secondary wastes were generated by operation of the ISUGS System. The only secondary wastes were used PPE, disposed in accordance with INEEL procedures.
Waste containment and disposal	No wastes were generated by the ISUGS System, so no containment was necessary. Baseline sampling required shielding and containment when removed from the canal.
Equipment Specifications and Operational Parameters	
Technology design purpose	To identify radioactive components in waste objects being sent to the Radioactive Waste Management Complex. Satisfy waste acceptance

Working Conditions	
	criteria of the complex.

Specifications	▪ Canberra GL0515 Low-Energy Germanium Detector, with an energy range of 3 keV - 2 MeV
	▪ Canberra detector electronics, including transistor reset pre-amplifier and high-voltage power supply
	▪ Single-port, multiattitude liquid nitrogen cryostat and remote detector chamber
	▪ Custom submersible housing with electronics/vent umbilical, and 10 externally mounted interchangeable shielded collimators
	▪ Canberra *InSpector* ä Multi-Channel Analyzer
	▪ A 366-MHz Dell *Inspiron 3500* notebook computer
	▪ A 500-MHz Dell *Optiplex GX1p* desktop computer
	▪ Canberra software programs:
	    ▪ Genie 2000 Gamma Acquisition and Analysis
	    ▪ Genie 2000 Detector Quality Assurance
	    ▪ Genie 2000 Interactive Peak Fit
	    ▪ PROcount 2000 Counting Procedures
	    ▪ ISOCS
	▪ Wall-mounted, detector support bracket with:
	    ▪ Adjustable X-Y slides
	    ▪ Dual-elevation wire rope rigging attachments
	    ▪ Detector housing strongback with distance measurement device
	▪ Underwater video system with pan, tilt, zoom, and lighting capabilities.

Portability	The ISUGS unit is mounted on a bracket on the canal wall and lowered by the use of an electric hoist into the canal.
Components Used	
Work area preparation	Additional radiological instrumentation and PPE as needed for working in a radiological environment.
PPE	Full PPE required.
Utilities/Energy Requirements	
Power, fuel, etc.	No specific utilities/energy requirements for this demonstration. However, the innovative and baseline technology instrumentation utilized batteries for operation. Nitrogen purge gas used for the ISOCS.

SECTION 3
PERFORMANCE

Demonstration Plan

Problem Addressed

D&D projects at the INEEL must identify and quantify radiological contamination. As part of the characterization process, the ISUGS technology is operated underwater and provides dose rate and isotopic details for making regulatory decisions about objects stored in the reactor canals. The ISUGS system provides near real-time information essential for D&D activities and also helps reduce exposure of the D&D work force to radiation.

This demonstration was designed to determine if the ISUGS System can be used for underwater radiological characterization to meet the Radioactive Waste Management Complex waste acceptance criteria by replacing the current baseline technology. The baseline technology involves deploying a radiation detector on a “extendable pole” to measure levels of radioactivity. Samples are collected to identify specific radioisotopes through laboratory analysis. All waste streams must be properly characterized before disposal. Historically, samples have been collected from this facility and scaling factors used for quantifying specific alpha- and beta-emitting radionuclides. Scaling factors are calculations of the decay and generation of progeny for the various known isotopes. These scaling factors were based on the cobalt-60 and cesium-137 concentrations. The process of developing scaling factors consists of an analysis of the waste combined with calculations of the decay and generation of progeny for the various known isotopes. The calculations result in the ability to measure the radiation level of the waste and apply a normalization factor to a long list of isotopes and to calculate the curie concentration of each isotope. These scaling factors may address more than 100 isotopes. This demonstration included samples being collected and analyzed to compare with data obtained from the ISUGS System. These data provided information necessary to confirm the scaling factors for the alpha- and beta-emitting radionuclides associated with objects found in the canal. This demonstration provided information necessary to compare reductions in cost, worker exposure, turn-around times for analytical results, and time required for decision making by the D&D program. It was also used to evaluate scaling factors developed for other objects at the Materials Test Reactor. The scaling factor may be useful for other radiological characterization processes involving pools or canals.

Demonstration Site Description

The INEEL site occupies 569,135 acres (approximately 890 square miles) in Southeast Idaho. The site consists of several primary facility areas situated on an expanse of otherwise undeveloped, high-desert ecosystem. Structures at the INEEL are clustered within the primary facility areas, typically less than a few square miles in size and separated from each other by miles of undeveloped terrain.

The Test Reactor Area is located in the southwest portion of the INEEL, 4.9 miles northwest of the Central Facilities Area. The major mission of the Test Reactor Area is to conduct scientific and engineering experiments for and in behalf of DOE and to support various nuclear and nonnuclear programs. The area was established in the early 1950s with the development of the Materials Test Reactor or Test Reactor Area-603. The Materials Test Reactor was shut down in 1970, and the building is now used for offices, storage, and test areas in support of activities at the INEEL’s Idaho Nuclear Technology and Engineering Center. The canal of the Materials Test Reactor has been the storage location for a number of radioactively contaminated objects. These contaminated objects are being characterized to facilitate their removal and disposal. The Materials Test Reactor is a three-story structure with a three-floor open bay. Walls and floors are of heavy-duty concrete, with the roof of steel construction. The building is approximately 45,184 square feet in plan area and has a 30/5-ton bridge crane and a 2-ton bridge crane over the Materials Test Reactor canal.

Major Objectives of the Demonstration

The major objectives of this demonstration were to evaluate the ISUGS System against the baseline sampling in the following areas:

- Cost effectiveness
- Safety
- Ease of use
- Limitations.

Major Elements of the Demonstration

The intent of this demonstration was to gather information helpful in deciding which technology, i.e., ISUGS or baseline sampling, would improve or enhance D&D activities. The purpose of this field demonstration was to assess the effectiveness of the ISUGS System in providing accurate radiological characterization data of objects stored in the canal at the Materials Test Reactor. By using ISUGS technology, the waste stream from the Materials Test Reactor was more thoroughly characterized simply by covering an entire object for gamma characterization and applying a scaling factor for the alpha- and beta-emitting radionuclides. This in situ technology reduced the amount of samples required for an accurate characterization and reduced the hazardous waste generated from the sampling process. By reducing the number of samples collected, worker exposure was also reduced.

The major elements evaluated for this demonstration were:

- Survey time
- Documentation
- Number of workers required
- Safety
- Cost
- Feedback
- Advantages/disadvantages.

The ISUGS System demonstration started May 10, 2000, and was completed May 22, 2000. It took place at the canal of the Materials Test Reactor (Test Reactor Area-603). The ISUGS System was shipped to the INEEL as radioactive material. It required a radiological control technician at the Central Facilities Area to inspect the shipment. After this inspection was completed, the ISUGS System was shipped to the Test Reactor Area by a certified hazardous shipper and driver. Setup of the equipment required both Framatome and INEEL personnel. The wall bracket was placed in an area above the canal without any radiological objects below. After the bracket had been appropriately assembled and attached, the submersible unit was lowered into the canal. This was done using the electric crane that can lift in excess of 500 pounds and was performed in accordance with the DOE Hoisting and Rigging manual.

After lowering the unit into the canal, the *Inspector* (the electronic components of this technology) was placed outside the contaminated area. This helped prevent the majority of the costly components from becoming contaminated. The canal depth is 18 feet, and the length of the system cord extends 75 feet, allowing the system to be out of the contamination area. Next, a MTR Operator attaches a extendable pole loop around a underwater object and move the object over to the ISUGS for scanning.

The ISUGS System was allowed to count for 90 to 300 seconds, depending on the radiation levels associated with the object being counted.

Currently, the baseline radiological characterization process involves the use of a radiation detector on a “extendable pole” to locate and identify radiation levels. Samples are collected from objects to identify and quantify the radionuclides. During the sampling process, a potential for increased worker exposure exists. The sample collection process requires additional safety precautions to shield the sample and prevent the spread of contamination during removal and transport to the laboratory for analyses. Analytical results can take up to three months, delaying D&D activities associated with the dispositioning of characterized objects. This process is tedious and time consuming and creates a secondary waste stream.

Results

The performance of the two technologies is compared in Table 2. The ISUGS technology identified and characterized the objects submerged in the Materials Test Reactor canal quickly and provided isotopic information that satisfied the waste acceptance criteria of the Radioactive Waste Management Complex.

Specific advantages of the new innovative technology of ISUGS include:

- Cost reductions for object characterizations – reduction in labor hours and sampling.
- Accelerated D&D schedule – shorter characterization times and reduced need for sampling objects in the canal.
- In situ near real-time radiological measurements.
- Reduced exposure of personnel to radiation – unit is operated underwater, reducing exposure. Reduced sampling also has the effect of reducing the exposure of personnel to radiation.
- No secondary waste stream created.

Table 2. Performance comparison between the ISUGS System and baseline technology.

Performance Factor	Baseline Surveying and Sampling Technology	ISUGS Technology
Personnel/equipment/time required to characterize objects	Personnel: • 2 radiological control technicians • I Test Reactor Area operator • Data collector • Test engineer Equipment: • 1 Portable NaI Detector (Eberline RO-7) • 1 field logbook • Extendable pole • Area radiation monitors (1 continuous air monitor, 2 radiation area monitors) Time: • 5 minutes average	Personnel: • 1 radiological control technician • 1 Test Reactor Area operator • Framatome operator • Data collector • Test engineer Equipment: • 1 ISUGS System • 1 field logbook Time: • 7.5 minutes average
Time required to collect and analyze samples	Personnel: • 2 radiological control technicians • 1 Test Reactor Area operator • Data collector • Test engineer Equipment: • Sampling shield/packaging • Laboratory analysis for isotopic determination • Area radiation monitors Time: • 65 minutes average to take sample • 65 days to obtain sample results	Equipment: • None Time: • None
Time required to generate report	Personnel: • 1 data collector • Test engineer Equipment: • 1 personal computer • 1 field logbook Time: • 35 minutes	Personnel: • 1 test engineer (Framatome) Equipment: • 1 personal computer • 1 field logbook • Canberra software Time: • 5 minutes
Total time per technology	• 175 minutes	• 15 minutes
PPE requirements	• Clothing adequate for entrance to radiologically contaminated area	• Clothing adequate for entrance to radiologically contaminated area
Superior capabilities	• Technology is well known and accepted for characterization of objects to meet Radioactive Waste Management Complex waste acceptance criteria.	• ISUGS System was considered much easier to use • It is much faster and more efficient in collecting data • It can provide near real-time data.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline Technology

Currently, the radiological characterization process involves the use of a radiation detector on a “extendable pole” to locate and identify the radiation levels. Samples are collected from objects to identify and quantify the radionuclides. During the sampling process, a potential for increased worker exposure exists. The sample collection process requires additional safety precautions to shield the sample and prevent the spread of contamination during removal and transport to the laboratory for analyses. Analytical results can take up to three months. This process is tedious and time consuming and creates a secondary waste stream. There are various manufacturers that produce variations of the instruments used for the baseline technology.

Other Competing Technologies

Various survey technologies are available such as plastic scintillation, NaI detectors, and germanium detectors. However, unlike these detectors, the ISUGS technology can be used underwater. Once data have been recorded on the computer, the file can be downloaded and interpreted through the Canberra software to visually display characterization results.

Technology Applicability

The innovative technology is fully developed and commercially available. Its superior performance over the baseline technology makes it a prime candidate for deployment at commercial sites as well as across the DOE complex.

Patents/Commercialization/Sponsor

The ISUGS System is commercially available from:

Framatome Technologies, Inc.
3315 Old Forest Road, P.O. Box 10935
Lynchburg, VA 24506-0935

Point of Contact: Matthew Hernandez
Phone: (804) 832-2408

Canberra Industries (ISOCS)

800 Research Parkway
Meriden, CT 06450

Point of contact: Carlton Green, (208) 788-8925 cgreen@canberra.com

SECTION 5
COST

Introduction

This section compares cost between the innovative and baseline technology for underwater isotopic characterization of radioactively contaminated equipment. The innovative technology cost is approximately half of the baseline technology cost for a field screening level of characterization of a test train (i.e., an experimental fuel-bundle assembly used to test temperature and flow inside the bundle) being stored underwater.

Methodology

This analysis for underwater isotopic characterization is based on government ownership of the innovative technology equipment, and the baseline technology consists of laboratory analysis of samples at an onsite laboratory. Government ownership of the equipment was used in this analysis and the purchase price of the equipment is included in the cost comparison by developing an hourly rate for using the equipment based on amortizing the purchase over the anticipated service life of the equipment. The development of the amortization of the purchase price and hourly rate is described in Appendix B. At this time, Framatome Technologies, Inc. has not made final decisions about offering the innovative technology as equipment for purchase or rental. In the event that they proceed with plans for rental and purchase, they have developed some preliminary prices used in this report.

Prior to beginning the characterization work, the innovative and baseline technology included a scan of the test train using an underwater survey meter. The innovative technology characterization work consisted of counting at three locations on the test train and did not include any quality assurance procedures such as quality assurance samples or a review of the data results for data quality issues. The counting was performed at the top, midsection, and bottom areas of the test train. The baseline technology characterization consisted of collecting material from three locations on the test train. The material was collected using an extendible pole with a hacksaw attachment to cut the material and a catch pan to retrieve the material to be sampled.

This material was further segmented to provide five samples for laboratory analysis. The baseline technology included underwater counting, sample collection, and sample preparation. The baseline technology sampling includes standard quality assurance procedures and data validation. This quality assurance resulted in an additional sample for quality assurance purposes, and brings the total number of laboratory analyses for the baseline to six. For safety reasons, segmenting and preparing the samples required a chemical fume hood. This was not available in the building where the test train was stored, so the final sample preparation took place in a nearby building that had a hood.

In this demonstration, the vendor's personnel performed the characterization work for the innovative technology. The vendor's personnel also collected samples for the baseline technology. This cost analysis assumes that both the innovative technology and the baseline technology use site labor. The crews used in the cost analysis are based on the test engineer's judgment and include two radiological control technicians, two equipment operators, and one job supervisor for the innovative technology. The baseline technology crew is assumed to include one sample technician, one equipment operator, and two radiological control technicians. The cost analysis is based on the standard labor rates used at the INEEL. Rates for common construction equipment and vehicles are based on the standard rates that the INEEL charges projects for use of equipment from its fleet.

In some cases, the activity durations observed during the demonstration do not represent the cost of typical work because of the artificial effects imposed on the work. These artificial effects are the result of the need to collect data, first-time use of the equipment at the INEEL, and other effects associated with the demonstration. In these cases, the observed durations are adjusted before using them in the cost analysis. An example of this type of artificial effect on the work involved a situation in which the computer equipment was moved from one location to another to be closer to the work and allow easier viewing of the underwater area. This also required changing the length of the connector cables and recalibration because of the changed cable length. The time spent moving the computer and adjusting the cables was not included in the cost analysis.

In some cases, events occurred during the demonstration that are typical of normal work; but these events were not related to the technology and tended to distract or overly complicate the comparison of technology costs. These types of events were not included in the cost analysis. Examples include breakdown of the continuous air monitors that required work shutdown, tangling of the bridge-crane cables as the objects underwater were moved, and delays to work due to radiological control technicians being unavailable.

Additional details of the basis of the cost analysis for the waste stockpile characterization are described in Appendix B.

Cost Analysis

Costs to Procure Innovative Equipment

There are several alternatives available for acquiring the innovative technology. The costs associated with these acquisition alternatives are indicated in Table 3.

Table 3. Innovative technology costs.

Acquisition Option	Item Description	Cost
Purchase	Detector and watertight case	$200,000
Rent equipment	Detector and watertight case	$2,200/day
Vendor-provided service	Crew and equipment	$3,830/day

Note: Rates shown are preliminary; actual rates will vary.

Unit and Fixed Costs

Table 4 shows unit costs, fixed costs, and production rates for the innovative and baseline technologies. The fixed costs are the sum of the line items shown in Appendix B (Table B-2 and B-3) that do not vary directly with the size of the job. The unit costs are the sum of the line items shown in Table B-2 and B-3 that do vary with the size of the job. For the innovative technology, this sum is divided by the number of locations scanned (three). The sum is divided by the number of samples collected (five) for the baseline technology unit cost.

Table 4. Summary of unit and fixed costs.

COST ELEMENT	INNOVATIVE COST	BASELINE COST
Fixed Costs	$4,037.93	$1,400.02
Unit Costs	$889.33 each scan	$2,855.41 each sample

The fixed costs for the innovative technology include the following line items shown in Table B-3: Setup of the underwater table, shipping the ISUGS System, transporting the ISUGS System to the work area, assembly and mounting, nitrogen charging and calibrating, rigging and lifting, positioning the ISUGS System in the pool, the ISUGS System cooldown period after charging with nitrogen, raising the ISUGS System from the pool, deconning the equipment, returning the equipment to storage, packing and transporting the ISUGS System.

The unit cost for the innovative technology includes the following line items shown on Table B-3: Prejob briefing, don personal protective equipment (PPE), move object to table, RO-7 survey object location, ISUGS System scan object location, return object to origin, solid waste transport, disposal fee and taxes.

The fixed costs for the baseline technology include the following line items shown in Table B-2: Setup of the underwater table, transport to work area, prepare laboratory fume hood to prepare samples, transport to the hood, pack/deliver samples, solid waste transport, disposal fee, and taxes.

The unit cost for the baseline technology includes the following line items shown in Table-B-2: Pre-job briefing, don PPE, move object to table, survey location on object, rig object for cutting, cut samples from object, return object to origin, doff PPE and exit, don PPE for hood area, size samples in hood, doff PPE and exit, lab analysis of samples and sample validation.

Break-Even Point

The costs for the innovative technology and baseline technology for work similar to the demonstration are shown in Figure 5. At the point where the lines cross, the technologies are approximately equal for cost effectiveness. As shown in Figure 5, the innovative technology is more cost effective beyond the break-even point.

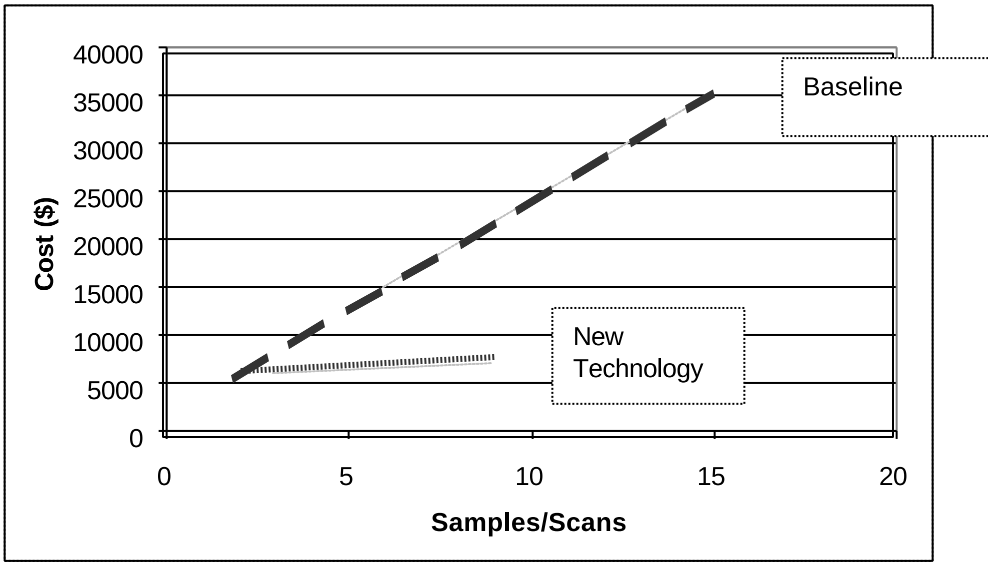

Figure 5. Break-even analysis.

Payback Analyses

For cases in which the innovative technology is purchased, the savings over the baseline technology is approximately $2,990/location scanned over the baseline technology for characterizing one piece of equipment per job and by scanning at three locations on each piece of equipment. At this rate of savings, approximately 67 scans are required to recover the purchase price of the innovative technology equipment ($200,000/$2,990 per scan = 67 scans).

Observed Costs for Demonstration

Figure 6 summarizes the observed costs for the innovative and baseline technologies based on characterizing one piece of equipment by scanning at three locations with the innovative technology and by laboratory analysis of six samples for the baseline. Details of these costs are shown in Appendix B and include Tables B-2 and B-3, which can be used to compute site-specific cost by adjusting for different labor rates, crew makeup, etc.

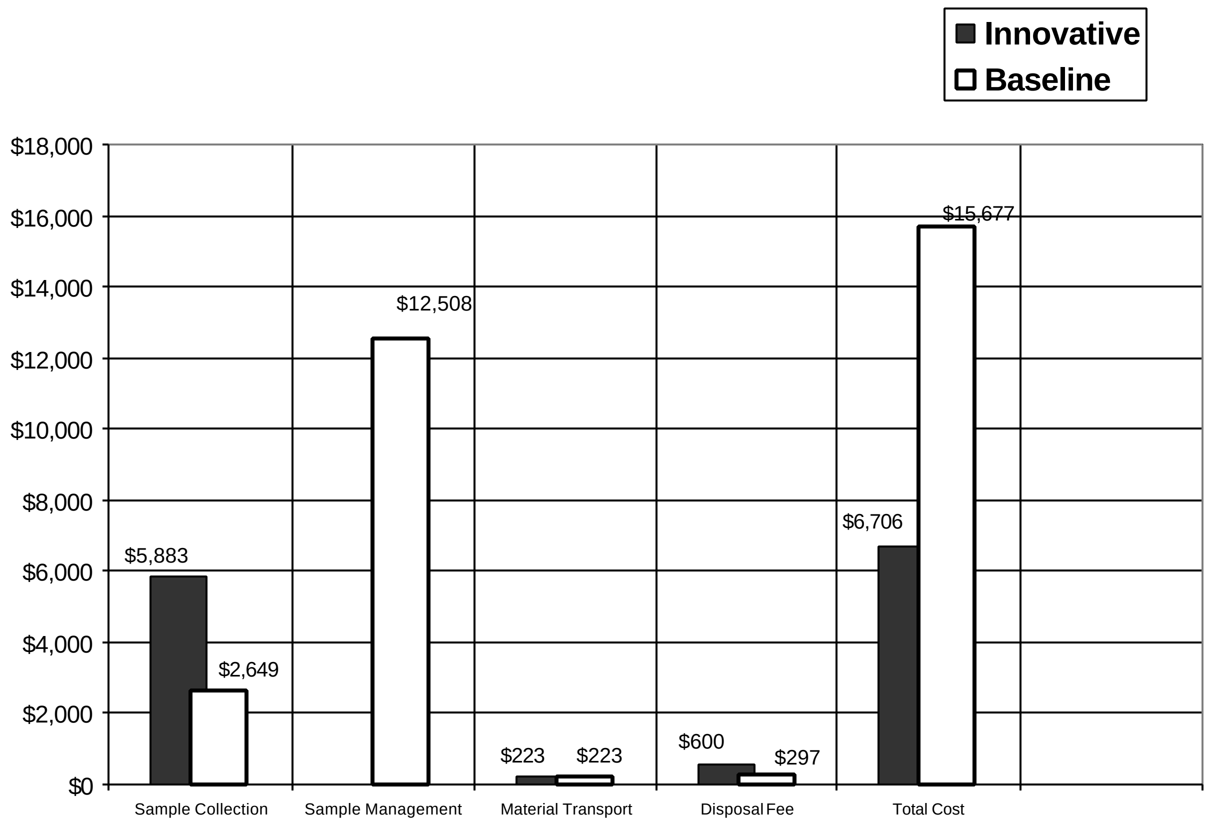

Figure 6. Summary of technology costs.

Cost Conclusions

The innovative technology costs for "Investigation and Monitoring/Sample Collection" (work breakdown structure 4.07.14) are primarily fixed costs associated with setup and work preparations for a job consisting of characterizing one piece of equipment. As the size of the job increases, the fixed costs remain relatively constant and are less of a factor in the total cost. Consequently, the comparison of the innovative technology to the baseline technology is sensitive to the job size. For a job that requires characterizing 10 pieces of equipment, the innovative technology would cost approximately one-fifth the amount of using the baseline technology for characterization performed similarly to this demonstration. In addition to job size, the cost of sample collection for the baseline can vary because of the following site-specific requirements:

- Type of material sampled (snipping of a wire takes a couple of minutes compared with sawing off a structural member, which can take one hour)
- Number of samples needed to characterize a single piece of equipment (three locations for five samples were used in these demonstrations, but more samples or fewer samples may be collected for real work situations)
- The type of isotopic analyses required (this cost analysis is based on each sample being analyzed for gross alpha, carbon-14, iron-55, nickel-59/63, strontium-90, technetium-99, and gamma isotopes, and more analyses or fewer may be required in real work situations).

The innovative technology's quality assurance work procedures were not as rigorous as the procedures used for the baseline technology. For work situations requiring rigorous quality assurance procedures, the cost of the innovative technology quality assurance will be greater. This affects cost comparison with the baseline technology.

Work situations that favor using the baseline technology are listed below:

- Few samples for each piece of equipment sampled (for example, three rather than the five used in this demonstration)
- Fewer types of analyses for each sample (for example, three analyses rather than the seven used in this demonstration)
- Rigorous quality assurance required (assume collection of at least one sample for laboratory analysis).

In this situation, the baseline technology and innovative technology are approximately equal in cost for characterizing one piece of equipment. For the situation in which rigorous quality assurance and characterization of 10 pieces of equipment are required, the innovative technology is two-thirds the cost of the baseline technology.

The innovative technology and baseline technology costs for “Materials Handling/Transportation” (work breakdown structure 4.13) and “Disposal Facility” (work breakdown structure 4.32) may vary in cost from one DOE site to the next. But the variation in these costs is not anticipated to affect the cost comparison between the innovative technology and the baseline technology.

The innovative technology cost savings over the baseline technology will vary depending on the site-specific requirements of the work. For most real work situations, the innovative technology should cost one-half to two-thirds that of the baseline and may save significantly more if the work is especially adverse to the baseline (many samples required for each piece of equipment and many isotopic analyses) or if the quality assurance requirements are not rigorous.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

The ISUGS System meets the requirements for 10 CFR, Chapter III, DOE, Part 835, “Occupational Radiation Protection.” It also meets the requirements specified in DOE-STD-1098-99, “Radiological Control,” dated July 1999. For this demonstration, a test plan and the technical procedure requirement covered the use of the ISUGS System under the INEEL Large-Scale Demonstration and Deployment Project. The ISUGS unit was considered to be radioactively contaminated, so it was packaged and transported in accordance with Department of Transportation hazardous material requirements.

Safety, Risks, Benefits, and Community Reaction

The safety issue associated with the use of the ISUGS System is primarily moving the instrument to the canal area and lowering it into the water for characterization surveys. Engineers use a wall-mounted bracket and a local electrical hoist to carefully move the instrument and its shielding and other components. Minimal risks associated with moving the ISUGS System are acceptable to the public.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The ISUGS technology is mature and provided meaningful, near real-time survey data during the INEEL demonstration. Operating the unit required vendor support, which was part of the service provided under the contract. According to users and recipients of the data, the technology is much faster and easier to use than the baseline technologies of surveying and sampling. The system provides better quality documentation including isotopic results. Items that should be considered before implementing the ISUGS System include the following:

- Daily instrument checks on the detector to ensure the ISOCS is performing properly
- Preventative maintenance on the detector and underwater components.

Technology Limitations and Needs for Future Development

As mentioned above, this demonstration proceeded successfully. The ISUGS technology was able to characterize objects underwater and served to enhance the scaling factors in use at the INEEL for packaging waste for disposal at the Radioactive Waste Management Complex. The ISUGS technology is limited to underwater applications and should not be deployed directly over fuel rods due to concerns over accidental breakage. Another limitation is objects which cannot be moved to the ISUGS unit for scanning due to weight, size, radiation and safety concerns, or deteriorating condition. Some objects could break when moved within the pool water.

Technology Selection Considerations

Based on the INEEL demonstration and the information provided in Appendix B, the ISUGS technology is a better method for conducting underwater characterization measurements than the baseline technologies of surveying and sampling. The ISUGS technology can provide better coverage of the objects being characterized underwater and provides near real-time isotopic results.

The technology is available as a service from the vendor if the end user cannot afford to purchase ISUGS or does not have sufficient work scope to justify purchase of the ISUGS at $200,000.

APPENDIX A
REFERENCES

Tyger, G. L., February 11, 1999, *Engineering Design File*, INEEL, WROC-EDF-392, Rev. 1., p. 15 of 24.

APPENDIX B
COST COMPARISON

Basis of Estimated Cost

The activity titles shown in this cost analysis come from work observation. In the estimate, the activities are grouped under higher-level work titles per the work breakdown structure shown in the Environmental Cost Element Structure.

Costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing the hourly rates:

- This cost analysis assumes innovative technology is owned by the government.
- The hourly rates for government-owned equipment that has no standard fleet rates are based on general guidance contained in Office of Management and Budget Circular A-94, “Cost Effectiveness Analysis.” This involves amortizing the purchase price of the equipment over its anticipated service life. It also includes a procurement cost of 5.2% of the purchase price and annual maintenance costs. A service life of five years is assumed for the innovative technology equipment.
- Such equipment as vehicles used in the course of the demonstration is commonly included in the site motor pool. Equipment rates for these vehicles stem from standard fleet rates at the INEEL.
- The standard labor rates established by the INEEL are used in this estimate and include salary, fringe, department overhead, material-handling markup, and facility service-center markup.
- Equipment and labor rates do not include the Bechtel BWXT Idaho, LLC general and administrative markups. These markups are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. General and administrative rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site’s rates to this analysis without having to first back out the rates used at the INEEL.

The analysis does not include costs for oversight engineering, quality assurance, administrative costs for the demonstration, or work plan preparation.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity are described in this section.

Investigations and Monitoring/Sample Collection, Contaminated Building/Structure Samples

SET UP UNDERWATER TABLE: This activity includes placing a work platform in the underwater area near the objects to be surveyed. The table will support the ISUGS System in the innovative technology portion of the demonstration and support the object being sampled in the baseline technology portion of the demonstration. The time required for this activity is based on the judgment of the test engineer.

SHIP ISUGS SYSTEM: This activity is observed costs for shipping the ISUGS System from Lynchburg, Virginia, to Idaho Falls, Idaho, and back.

TRANSPORT TO WORK AREA: This activity includes picking up the ISUGS System from the warehouse in the case of the innovative technology and transporting the baseline technology tools and equipment from a storage facility to the work area. The time required for this activity is based on the judgment of the test engineer.

PREJOB BRIEFING: The duration of the prejob safety meeting is based on the observed time for the demonstration. The labor costs for this activity are based on an assumed crew rather than the actual demonstration participants, and all subsequent activities are based on the assumed crew.

DON PPE AND ENTER: This activity includes the labor and material cost for donning the articles of clothing listed in Table B-1 and entry into the radiological control zone. The radiological control technician who allows the crew into and out of the radiological control zone and the job supervisor do not enter the zone with the crew (do not don or doff PPE). In the case of the baseline, there is an entry event for collecting samples and a later entry event, in another location, to prepare the samples for laboratory analysis. The estimates assume that the workers leave the radiological control zone for lunch breaks, and this requires an additional doffing and donning of PPE.

Table B-1. Cost for PPE (per man/day).

Equipment	**Cost Each**	**Number of Times Used Before Discarded**	**Cost Each Time Used ($)**	**Number Used Per Day**	**Cost Per Day ($)**
Boot covers each	$0.19	1	$0.19	4	$0.76
Rubber boots with liner pair	$35.30	50	$0.71	1	$0.71
Glove liners pr. (cotton inner)	$0.40	1	$0.40	2	$0.80
Rubber gloves pair (outer)	$1.20	1	$1.20	2	$2.40
Coveralls (white Tyvek)	$3.30	1	$3.30	2	$6.60
Hood	$0.85	1	$0.85	2	$1.70
Hard hat	$11.45	30	$0.38	1	$0.38
Safety glasses	$4.80	30	$0.16	1	$0.16
TOTAL COST/DAY/PERSON					**$13.51**

ASSEMBLE AND MOUNT: This activity applies only to the innovative technology and includes assembly of the detector, checking connections, and mounting in the watertight housing. The time required for this activity is based on the duration observed in the demonstration.

NITROGEN CHARGE AND CALIBRATE: This activity applies only to the innovative technology and includes charging ISUGS with nitrogen and calibrating the detector. This is performed at 36-48 hour intervals. The time required for this activity is based on the duration observed in the demonstration.

RIG FOR LIFTING: This activity applies only to the innovative technology and includes attaching cables that allow ISUGS to be lifted and moved using the bridge crane. The time required for this activity is based on the duration observed in the demonstration.

POSITION ISUGS SYSTEM IN WATER: This activity applies only to the innovative technology and includes placing the ISUGS System on the underwater table. The time required for this activity is based on the duration observed in the demonstration.

ISUGS SYSTEM COOLDOWN: This activity applies only to the innovative technology and includes allowing the ISUGS System to reach equilibrium with the water temperature. The time required for this activity is based on the duration observed in the demonstration.

MOVE OBJECT TO TABLE: This activity apples to both the innovative technology and the baseline technology and includes attaching cables to the test train and moving the test train to the underwater table by means of the bridge crane. The time required for this activity is based on the duration observed in the demonstration for moving the test train.

RO-7 SURVEY OF OBJECT LOCATIONS: This activity includes counting at selected locations on the test train using the RO-7 underwater survey meter. In the case of the innovative technology, the locations are the top, midsection, and bottom of the test train. Three locations were surveyed for the baseline technology at the locations to be sampled. The time required for this activity is based on the overall average time required for an RO-7 count that was observed over the course of the demonstration.

ISUGS SYSTEM SCAN OBJECT LOCATION: This activity applies only to the innovative technology and includes ISUGS System counts at the top, midsection and bottom of the test train. The time required for this activity is based on the duration observed in the demonstration.

RIG OBJECT FOR CUTTING: This activity applies only to the baseline technology and includes attaching the test train to the underwater table in a way that keeps the test train from moving while the samples are cut. The time required for this activity is based on the duration observed in the demonstration.

CUT SAMPLES FROM OBJECT: This activity applies only to the baseline technology and includes using a hacksaw attached to a pole, and other methods, to cut three samples from the test train. The time required for this activity is based on the duration observed in the demonstration.

RETURN OBJECT TO ORIGIN: This activity applies to both the innovative technology and the baseline technology and includes using the bridge crane to move the test train back to the original position in which it was stored. The time required for this activity is based on the duration observed in the demonstration.

RAISE ISUGS SYSTEM: This activity applies only to the innovative technology and includes removing the ISUGS System from the water. The time required for this activity is based on the duration observed in the demonstration.

DOFF PPE: This activity applies to both the innovative technology and the baseline technology and includes the labor costs for doffing PPE and is based on the duration observed in the demonstration.

DECONTAMINATE EQUIPMENT: This activity includes decontamination of the ISUGS System for free release. The time required for this activity is based on the duration observed in the demonstration.

RETURN EQUIPMENT TO STORAGE: This activity includes transporting the equipment back to the storage area and unloading it. In the case of the innovative technology, this activity applies to the miscellaneous site-owned equipment needed for the demonstration and does not include costs for the ISUGS System. The activity duration is based on the test engineer's judgment.

PACK AND TRANSPORT ISUGS SYSTEM: This activity includes packing the ISUGS System in preparation for transport to the warehouse. The activity duration is based on the test engineer's judgment.

Sample Management/Data Validation/Data Evaluation (WBS 4.09)

The activities shown for Sample Management/Data Validation/Data Evaluation apply only to the baseline technology.

TRANSPORT TO HOOD: This includes transporting the samples to a different building with a chemical fume hood that will accommodate preparation of the samples for analysis. The time required for this activity is based on the duration observed in the demonstration.

DON PPE (FOR ENTRY TO THE AREA WITH THE HOOD): This activity includes donning PPE for entry into the radiation control area where the chemical fume hood is located. The PPE used is shown in Table B-1. The time required is based on the duration observed during the demonstration.

PREPARE HOOD: This activity includes preparing the hood for segmenting the samples. The time required is based on the duration observed during the demonstration.

SIZE SAMPLES IN HOOD: This activity includes segmenting the three samples collected from the test train into five samples and preparing a quality assurance sample (total of six samples). The time required is based on the duration observed during the demonstration.

DOFF PPE: This activity includes the labor costs for doffing PPE and is based on the times experienced for previous demonstrations.

PACK/DELIVER SAMPLES: This activity includes packing and transporting samples to an onsite laboratory for analysis. The activity duration used in the cost analysis is based on the test engineer's judgment.

SAMPLE LABORATORY ANALYSIS: This activity includes the fee for performing the following isotopic analyses for each sample:

- Gross alpha
- Carbon-14
- Iron-55
- Nickel-59/63
- Strontium-90
- Technetium-99
- Gamma Isotopes

The fee amount used in this cost analysis is based on laboratory fees at the INEEL.

SAMPLE VALIDATION: This activity includes validation of the lab analysis data for all the samples for the baseline technology. The amount of effort assumed in this cost analysis for the validation of the baseline data is based on typical validation times for other projects where three hours of review is required per sample.

Components Handling/Transportation (WBS 4.32)

SOLID WASTE TRANSPORT: This activity applies to both the innovative technology and the baseline technology and includes loading the waste onto a truck, transporting it to the disposal area, and unloading the waste. The activity requires 1 hour to load, 1/2 hour to transport, and 1 hour to unload for each trip based on previous experience at the INEEL.

Disposal Facility, Disposal Fees, and Taxes (WBS 4.13)

DISPOSAL: The laboratory analysis fee includes the cost of returning the sample remains. That effort is not shown as a separate cost in this analysis. This cost is for disposal of PPE used in the course of the work and is based on the assumption that each worker generates 0.66 cubic feet of waste per day. For both the innovative technology and the baseline technology, there are three workers that don PPE for each day of work. Disposal costs at the INEEL are assumed to be $150 per cubic foot of waste based on historic costs observed at the INEEL for operation of the disposal cell. These costs do not include costs for transportation, packaging, disposal facility closure, or long-term maintenance and surveillance.

Cost Estimate Details

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration, and all production rates so that site-specific differences in these items can be identified and a site-specific cost estimate can be developed.

Table B-2. Baseline technology cost summary.

Unit/ Fixed Cost	Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost: Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
	Facility Deactivation, Decommissioning, & Dismantlement								**Total Cost =**				**$ 15,677.09**
	INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURES SAMPLES (WBS 4.07.14)										Subtotal =		$ 2,648.81
Fixed	Set Up Underwater Table	ls	1,196.00	1	$ 1,196.00		8.00	2 ST, 2RCT	148.88	2SM	0.62		
Fixed	Transport to Work Area	ls	41.16	1	$ 41.16		0.50	2 ST	77.34	P, MT, RO7	4.98		
Unit	Pre-Job Briefing	ea day	102.93	1	$ 102.93		0.50	ST, JS, 2RCT, EO	198.84	MT, RO7, 2SM, CAM	7.02		
Unit	Don PPE (canal sampling)	ea	143.46	2	$ 286.92		0.50	ST, JS, 2RCT, EO	198.84	MT, RO7, 2SM, CAM	7.02	40.53	$13.51/PPEX3=$40.53
Unit	Move Object to Table	ea	105.33	1	$ 105.33		0.50	ST, JS, 2RCT, EO	198.84	MT,RO7,2SM,CAM,BC	11.81		
Unit	Survey Loc. on Object	ea	17.55	3	$ 52.66		0.08	ST, JS, 2RCT, EO	198.84	MT,RO7,2SM,CAM,BC	11.81		
Unit	Rig Object for Cutting	ea	193.10	1	$ 193.10		0.92	ST, JS, 2RCT, EO	198.84	MT,RO7,2SM,CAM,BC	11.81		
Unit	Cut Samples from Object	ea	157.99	3	$ 473.96		0.75	ST, JS, 2RCT, EO	198.84	MT,RO7,2SM,CAM,BC	11.81		
Unit	Return Object to Origin	ea	52.66	1	$ 52.66		0.25	ST, JS, 2RCT, EO	198.84	MT,RO7,2SM,CAM,BC	11.81		
Unit	Doff PPE and Exit	ea	51.47	2	$ 102.93		0.25	ST, JS, 2RCT, EO	198.84	MT, RO7, 2SM, CAM	7.02		
Fixed	Return Equipment to Stora	ls	41.16	1	$ 41.16		0.50	2 ST	77.34	P, MT, RO7	4.98		
	SAMPLE MANAGEMENT/DATA VALIDATION/DATA EVALUATION (WBS 4.09)										Subtotal =		$ 12,508.05
Fixed	Transport to Hood	ea	13.16	1	$ 13.16		0.17	2ST	77.34	P	1.62		
Unit	Don PPE (hood area)	ea	44.35	1	$ 44.35		0.22	2ST	77.34	MT, HD	2.64	27.02	$13.51/persondayX2
Fixed	Prepare Hood	ea	49.32	1	$ 49.32		0.62	2ST	77.34	MT, HD	2.64		
Unit	Size Samples in Hood	ea	17.33	6	$ 103.97		0.22	2ST	77.34	MT, HD	2.64		
Unit	Doff PPE and Exit	ea	13.33	1	$ 13.33		0.17	2ST	77.34	MT, HD	2.64		
Fixed	Pack/Deliver Samples	ls	59.22	1	$ 59.22		0.75	2ST	77.34	P	1.62		
Unit	Lab Analysis of Samples	ea	1,890.00	6	$ 11,340.00							1890.00	Lab fee ea sample
Unit	Sample Validation	ea	147.45	6	$ 884.70		3.00	CH	49.15				
	MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)										Subtotal =		$ 223.23
Unit	Solid Waste Transport	ls	223.23	1	$ 223.23		2.50	TD, LB, 1/4 EO	75.97	FB, 1/4FL	13.33		
	DISPOSAL FACILITY, DISPOSAL FEES AND TAXES (WBS 4.13)										Subtotal =		$ 297.00
Unit	Disposal Fees & Taxes	cf	150.00	1.98	$ 297.00							150	0.66cf/dayX1 day X3

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbreviation	Crew Item	Rate $/hr	Abbreviation	Equipment Item	Rate $/hr	Abbreviation	Equipment Item	Rate $/hr	Abbreviation
Sampling Technician	38.67	ST	Equipment Operator	37.10	EO	Mis Tools (hacksaw, etc.)	1.57	MT	Underwater RO-7	1.79	RO7
Chemist	49.15	CH	Truck Driver	34.35	TD	Pickup	1.62	P	Hood	1.07	HD
Radiation Control Tech	35.77	RCT	Laborer	32.34	LB	Flatbed Truck	12.50	FB	Continuous Air Monitor	3.04	CAM
Job Supervisor	51.53	JS				Survey Meter	0.31	SM	Bridge Crane	4.79	BC
						Fork Lift	3.30	FL			

Notes:

1. Unit cost = (labor + equipment rate) $\times$ duration + other costs, or = (labor + equipment rate)/production rate + other costs.
2. Abbreviations for units: ls = lump sum, ea = each.
3. Other abbreviations: PPE = personal protective equipment, Decon = decontaminate, Loc = location, Equip = equipment, Tech = technician, Prod = production.

Table B-3. Innovative technology cost summary.

Fixed/ Unit Costs	Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost: Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
	Total Cost =												**$ 6,705.92**
	INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURES SAMPLES (WBS 4.07.14)										Subtotal =		$ 5,882.69
Fixed	Set Up Underwater Table	ls	1,094.72	1	$ 1,094.72		8.00	2 LB, 2RCT	136.22	2SM	0.62		
Fixed	Transport to Work Area	ls	85.01	1	$ 85.01		0.50	2 LB	64.68	P, MT, RO7,IS	105.33		
Unit	Pre-Job Briefing	ea day	152.32	2	$ 304.64		0.50	JS, 2RCT, 2EO	197.27	MT, RO7, 2SM, CAM,IS	107.37		
Unit	Don PPE (canal sampling)	ea	192.85	4	$ 771.40		0.50	JS, 2RCT, 2EO	197.27	MT, RO7, 2SM, CAM,IS	107.37	40.53	$13.51/PPE X 3=$40.53
Fixed	Assemble & Mount	ea	761.60	1	$ 761.60		2.50	JS, 2RCT, 2EO	197.27	MT, RO7, 2SM, CAM,IS	107.37		
Fixed	N Charge & Calibrate	ea	76.16	1	$ 76.16		0.25	JS, 2RCT, 2EO	197.27	MT, RO7, 2SM, CAM,IS	107.37		
Fixed	Rig for Lifting	ea	180.48	1	$ 180.48		0.58	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Fixed	Position ISUGS in Water	ea	103.13	1	$ 103.13		0.33	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Fixed	ISUGS Cool Down	ea	1,237.56	1	$ 1,237.56		4.00	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Unit	Move Object to Table	ea	154.70	1	$ 154.70		0.50	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Unit	RO7 Survey Object Loc.	ea	25.78	3	$ 77.35		0.08	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Unit	ISUG Scan Object Loc.	ea	51.57	3	$ 154.70		0.17	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Unit	Return Object to Origin	ea	77.35	1	$ 77.35		0.25	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Fixed	Raise ISUGS	ea	77.35	1	$ 77.35		0.25	JS, 2RCT, 2EO	197.27	MT,RO7,2SM,CAM,BC,IS	112.12		
Unit	Doff PPE and Exit	ea	76.16	4	$ 304.64		0.25	JS, 2RCT, 2EO	197.27	MT, RO7, 2SM, CAM,IS	107.37		
Fixed	Decon Equipment	ls	336.92	1	$ 336.92		2.00	RCT, LB	68.11	IS	100.35		
Fixed	Return Equip. to Storage	ls	85.01	1	$ 85.01		0.50	2 LB	64.68	P, MT, RO7, IS	105.33		
	MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)										Subtotal =		$ 223.23
Unit	Solid Waste Transport	ls	223.23	1	$ 223.23		2.50	TD, LB, 1/4 EO	75.97	FB, 1/4FL	13.33		
	DISPOSAL FACILITY, DISPOSAL FEES AND TAXES (WBS 4.13)										Subtotal =		$ 600.00
Unit	Disposal Fees & Taxes	cf	150.00	4.0	$ 600.00							150	0.66 cf/day X 2 days X 3

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbre-viation	Crew Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation
Sampling Technician	38.67	ST	Equipment Operator	37.10	EO	Mis Tools (hacksaw, etc.)	1.57	MT	Underwater RO-7	1.79	RO7
Laborer	32.34	LB	Truck Driver	34.35	TD	Pickup	1.62	P	Hood	1.07	HD
Radiation Control Tech	35.77	RCT				ISUGS	100.35	IS	Continuous Air Monitor	3.04	CAM
Job Supervisor	51.53	JS				Survey Meter	0.31	SM	Bridge Crane	4.75	BC
						Flat Bed Truck	12.50	FB	Fork Lift	3.30	FL

Notes:

1. Unit cost = (labor + equipment rate) × duration + other costs, or = (labor + equipment rate)/production rate + other costs.
2. Abbreviations for units: ls = lump sum, ea = each, loc = location, ft^3 = cubic feet.
3. Other abbreviations: PPE = personal protective equipment, Decon = decontaminate, Loc = location, Equip = equipment, Prod = production, Tech = technician, N = nitrogen.

Cost Conclusions

The innovative technology costs for “Investigation and Monitoring/Sample Collection” (work breakdown structure 4.07.14) are primarily fixed costs associated with setup and work preparations for a job consisting of characterizing one piece of equipment. As the size of the job increases, the fixed costs remain relatively constant and are less of a factor in the total cost. Consequently, the comparison of the innovative technology with the baseline technology is sensitive to the job size. For a job that requires characterizing 10 pieces of equipment, the innovative technology would cost approximately one-fifth the amount of using the baseline technology for characterization performed similarly to this demonstration. In addition to job size, the cost of sample collection for the baseline will vary in real work situations because of the following site-specific requirements:

- Type of material sampled (snipping of a wire takes a couple of minutes compared with sawing off a structural member, which can take one hour)
- Number of samples needed to characterize a single piece of equipment (three locations for five samples were used in these demonstrations, but more samples or fewer samples may be collected for real work situations)
- The type of isotopic analyses required (this cost analysis is based on each sample being analyzed for gross alpha, carbon-14, iron-55, nickel-59/63, strontium-90, technetium-99, and gamma isotopes, and more analyses or fewer may be required in real work situations).

The innovative technology's quality assurance work procedures were not as rigorous as the procedures used for the baseline technology. For work situations requiring rigorous quality assurance procedures, the cost of the innovative technology quality assurance will be greater. This affects cost comparison with the baseline technology.

Work situations that favor using the baseline technology are listed below:

- Few samples for each piece of equipment sampled (for example, three rather than the five used in this demonstration)
- Fewer types of analyses for each sample (for example, three analyses rather than the seven used in this demonstration)
- Rigorous quality assurance required (assume collection of at least one sample for laboratory analysis).

In this situation, the baseline technology and innovative technology are approximately equal in cost for characterizing one piece of equipment. For the situation in which rigorous quality assurance and characterization of 10 pieces of equipment is required, the innovative technology is two-thirds the cost of the baseline technology.

The innovative technology and baseline technology costs for “Components Handling/Transportation” (work breakdown structure 4.13) and “Disposal Facility” (work breakdown structure 4.32) may vary in cost from one DOE site to the next. But the variation in these costs is not anticipated to affect the cost comparison between the innovative technology and the baseline technology.

The innovative technology cost savings over the baseline technology will vary depending on the site-specific requirements of the work. For most real work situations, the innovative technology should cost one-half to two-thirds that of the baseline and may save significantly more if the work is especially adverse to the baseline (many samples required for each piece of equipment and many isotopic analyses) or if the quality assurance requirements are not rigorous.

APPENDIX C
ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
D&D	decontamination and decommissioning
DOE	Department of Energy
INEEL	Idaho National Engineering and Environmental Laboratory
ISOCS	In Situ Object Counting System
ISUGS	In Situ Underwater Gamma Spectroscopy
NaI	sodium iodide
OST	Office of Science and Technology
PPE	personal protective equipment